Designation: E2013 – 12

Standard Practice for Constructing FAST Diagrams and Performing Function Analysis During Value Analysis Study[1]

This standard is issued under the fixed designation E2013; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers a logical structure for the function analysis of a building project or process.

1.2 This practice provides a system to identify unnecessary costs of a project.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

E833 Terminology of Building Economics

E1557 Classification for Building Elements and Related Sitework—UNIFORMAT II

E1699 Practice for Performing Value Analysis (VA) of Buildings and Building Systems and Other Constructed Projects

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminologies E631 and E833.

4. Summary of Practice

4.1 This practice provides an organized approach for determining the needs and desires of the stakeholders during the Value Analysis (VA) of a project. These needs and desires are used in developing the functions of the project.

4.2 This practice establishes a logical procedure for allocating cost to each function.

4.3 Function analysis helps design professionals justify the value of their concepts. It also provides the stakeholders with a justification of their investments.

5. Significance and Use

5.1 This practice establishes a communication format through which all stakeholders can understand, analyze, revise, and agree on the purposes of the project. This practice presents a method by which stakeholders' needs and desires are compared to the cost to satisfy those needs and desires. This is done by identifying the low preference/high cost functions and high preference/low cost functions. These data will be used in the value analysis study as a basis to create alternative solutions.

5.2 This practice helps stakeholders, which include developers, owners, users, planners, contractors, architects, engineers, value analysts, cost professionals, and anyone who is responsible for the budget, construction, maintenance, or operation of the project.

5.3 A practice on performing value analysis of buildings and building systems and other constructed projects, Practice E1699, has been published. As part of the value analysis study, perform function analysis after the collection of relevant information and prior to the identification of alternatives. Function Analysis Systems Technique (FAST) data helps the user identify the alternatives that are highly valued with respect to their cost.

6. Procedure

6.1 Function analysis consists of five sequential steps: (*1*) select a building component, (*2*) define the needs and desires (functions), (*3*) classify functions, (*4*) allocate cost to each function, and (*5*) analyze the importance and expected performance level of the functions.

6.2 *Selection of a Building Component*—For cost-effectiveness, select building components that offer a significant opportunity for improvement of performance, reduction in cost, or both.

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[1] This practice is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

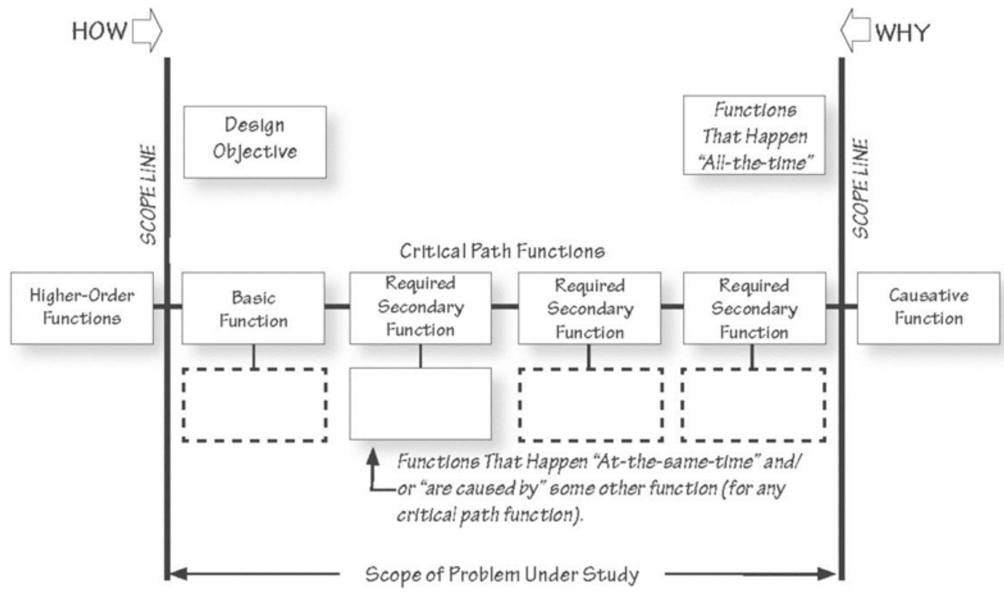


FIG. 1 Function Analysis Systems Technique (Technical FAST)

6.3 *Definition of Needs and Desires (Functions)*—Define each significant need or desire of the stakeholders in two words using an active verb and a descriptive noun. The two-word definitions are the functions of the project.

6.4 *Classification of Functions*—Categorize the functions of the building component as basic (essential to meet the stakeholders' needs) or supporting (enhances the satisfaction of the stakeholders' needs and desires).

6.5 *Distribution of Cost to Functions*—Divide cost of each component into smaller sections based on the specific use of the project and distribute cost to each function.

6.6 *Analysis of Functions:*

6.6.1 Analyze functions through a structured logical format called Function Analysis Systems Technique (FAST). FAST is a diagramming technique which specifically illustrates the relationships and interrelationships of all functions within a specific project using a "How-Why" logic pattern. There are two FAST variations.

6.6.2 One variation, known as Technical FAST, develops a critical path to define the basic needs of the project. This diagram helps the user calculate the ratio of total cost to critical functions.[3]

6.6.2.1 Technical FAST diagramming is effective in a specific situation or element within a project. The situation or element is an assembly or a portion of a construction design. Terms or functions are oriented to technical activities. A Technical FAST diagram has a specific structural form (Fig. 1).

6.6.2.2 There are four important concepts in a Technical FAST diagram:

1. "How-Why" Logic Questions
2. Scope Line
   - Higher Order Function
   - Basic Function
   - Required Secondary Functions
   - Causative Function
3. Critical Functions
4. Supporting Functions
   - Design Objectives
   - All The Time Functions
   - Caused-By/Same-Time Functions

6.6.2.3 Function analysis requires analyzing why a function exists and how a function satisfies other functions to complete the link between them. This "How-Why" logic assures that all the required functions are listed in the FAST diagram.[4]

6.6.2.4 Begin the Technical FAST diagramming with a higher order function of the project and two scope lines. All functions that the selected element fulfills are bounded by the two scope lines. The basic function is on the right of the left-hand scope line, and the higher order function is on the left. The purpose of the element or project for which a FAST diagram is developed is the higher order function. The relationship between the higher order function and the basic function is determined by asking "Why" the basic function candidate performs as it does. The answer should be the higher order function. The logic check must be completed by asking "How" the higher order function performs. The logical answer must be the basic function candidate. It is still necessary to confirm the required secondary function to the left of the right-hand scope line. When the "How" question is asked of this function, the answer will be an outside function candidate. The outside function is called the *causative function*, since it really starts the critical functions.

6.6.2.5 Determining the basic function often requires selecting functions from the list of suggestions and applying the "How" and "Why" questions. If the "Why" question is answered by another identified function, that function is the

[3] *Certification Examination Guidelines* , SAVE International, Dayton, OH.

[4] Snodgrass, T.J., and Kasi, M., *Function Analysis-The Stepping Stone to Good Value*, University of Wisconsin, Madison, 1983.

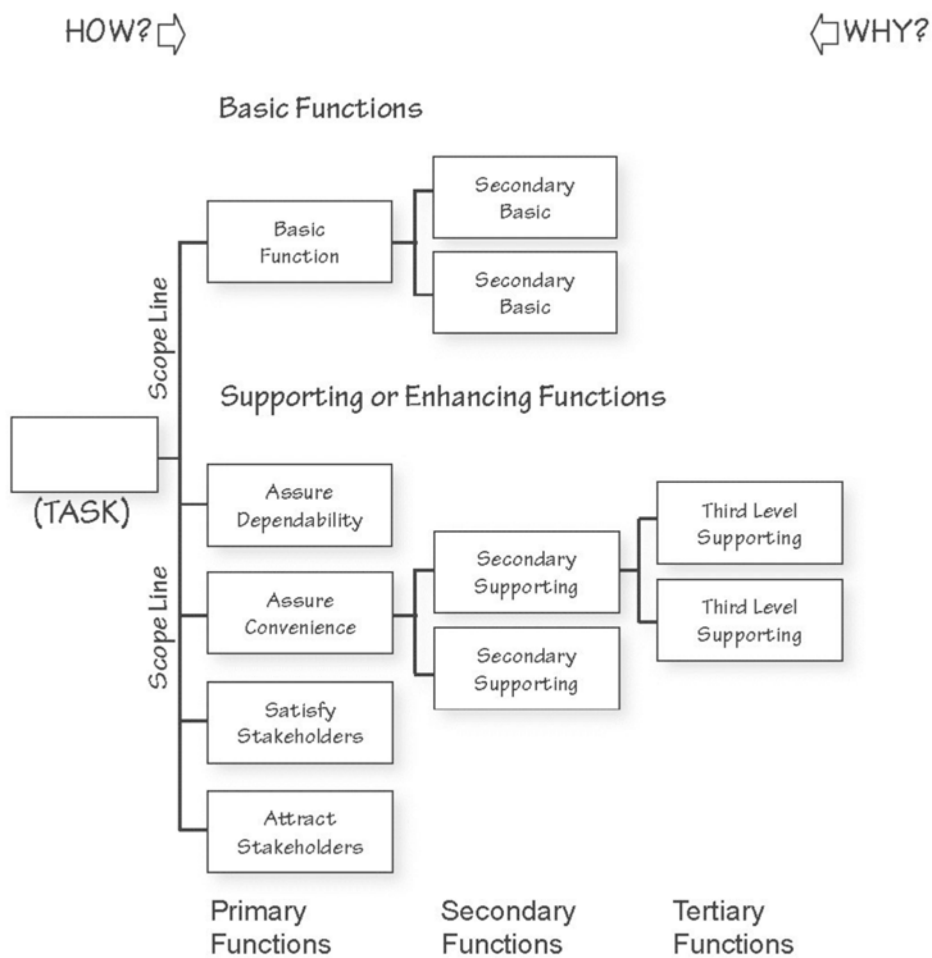


FIG. 2 Function Analysis System Technique (Task-Oriented FAST)

next candidate for the basic function. The function to the right becomes a required secondary function. Once the basic function is verified, the remaining required secondary functions are identified. This group makes up the *critical functions.*

6.6.2.6 The last group of functions is *supporting functions*. There are three types. The first type, *caused by* or *same time* functions, connects directly to a critical function. These functions result from the performance characteristics of particular critical functions and act as modifiers. The second type, *all-the-time functions*, modifies two or more of the critical functions. The third type, *design objectives*, represents specifications that are added to the design, often by the stakeholder or group that is developing or operating the process.

6.6.3 The second variation, known as Task-oriented FAST, creates distinct functions for stakeholders' concerns and is always headed by four primary functions: (*1*) assure dependability, (*2*) assure convenience, (*3*) satisfy stakeholders, and (*4*) attract stakeholders.

6.6.3.1 The Task-oriented FAST diagram logically displays the stakeholders' needs and desires (see Fig. 2). Task-oriented FAST diagramming is especially effective in the planning or conceptual phase. Use conceptual layout and building plans to develop these FAST diagrams.

6.6.3.2 There are four parts to the Task-oriented FAST diagram:

1. Task

2. Basic Functions
   - Primary
   - Secondary

3. Supporting Functions
   - Assure Dependability
   - Assure Convenience
   - Satisfy Stakeholders
   - Attract Stakeholders

4. Classify Functions
   - Primary
   - Secondary
   - Tertiary

6.6.3.3 The first step is to determine the task. The task satisfies the overall needs of the stakeholder. Establish a scope line just to the right of the task. Functions that answer "why perform the task" lie outside of the scope.

6.6.3.4 The second step is to separate the identified functions into basic and supporting functions. Basic functions are those which are essential to the performance of the task. Without the primary basic functions, the project or process will not work.

6.6.3.5 The third step is to group the remaining functions into the four primary supporting function groups. Supporting functions play an important role in a building. Structural engineers, for instance, concentrate primarily on the basic functions, with heavy emphasis on the primary supporting function *Assure Dependability*. Mechanical engineers and electrical engineers pay more attention to the supporting function *Assure Convenience*, while architects' ideas satisfy the basic and supporting functions *Satisfy Stakeholders* and *Attract Stakeholders*.

6.6.4 *Assure Dependability*—Any function that assures dependability has at least one of the following attributes:

6.6.4.1 Makes the elements of the project stronger or more reliable or effective,

6.6.4.2 Makes it safer to use,

6.6.4.3 Lengthens the life of the parts or minimizes maintenance cost, or both, and

6.6.4.4 Protects the environment.

6.6.5 *Assure Convenience*—Any function that assures convenience has at least one of the following attributes:

6.6.5.1 Modifies the basic function to make it convenient to use,

6.6.5.2 Enhances spatial arrangements,

6.6.5.3 Facilitates maintenance and repairs, and

6.6.5.4 Furnishes instructions and directions to stakeholders.

6.6.6 *Satisfy Stakeholders*—Any function that satisfies stakeholders has at least one of the following attributes:

6.6.6.1 Modifies the basic function to satisfy the individual desires,

6.6.6.2 Makes the stakeholders' life more pleasant; for example, minimizes noise, and

6.6.6.3 Makes the element appear to be better in the opinion of the stakeholder, but not necessarily in the opinion of the designer. (Sometimes these opinions are reflected in the standards and specifications of a particular agency/owner.)

6.6.7 *Attract Stakeholders*—Any function that attracts stakeholders and has at least one of the following attributes:

6.6.7.1 Emphasizes the visual aspect (sight) or other senses, and

6.6.7.2 Projects a favorable image (that is, trademarks or endorsement by public figures).

6.6.8 The fourth step is to classify the functions as primary, secondary, or tertiary.

6.6.8.1 The link between the task and basic functions is the sequence of the logical question "How-Why." The "How-Why" concepts must work between the selected task and the primary basic functions. These primary basic functions are interdependent and both are essential to the performance of the task.

6.6.8.2 Once the primary basic functions have been identified, the question "How" can be asked of each of the primary basic functions. Functions that answer the question "How" will be found in the expanding branches. These are the secondary basic functions. There must be two or more secondary basic functions to justify branching from the primary function.

6.6.8.3 In a similar manner, the secondary supporting functions branch to the right from the primary supporting functions when the question "How" is applied. Again, there must be two or more secondary functions to justify branching.

6.6.8.4 This rule also affects further branching off to the third (tertiary) level. Usually, the tertiary level completes the branching basic functions. The end of the branching is obtained when the hardware description or action is the noun of the function. The branches must also satisfy the "Why" question in the opposite direction, that is, logic check.

6.6.9 *Cost Estimate:*

6.6.9.1 Obtain cost estimates for the proposed building components and related sitework. Classification E1557 provides a useful format for allocating cost to functions.

6.6.10 *Function Cost:*

6.6.10.1 Most components of a building have more than one function to satisfy. Distribute cost of each component to each one of these functions, proportionate to their time cost. Use the elemental format, UNIFORMAT II, for the development of cost estimates. This expedites the completion of function costs. Allocate all life-cycle costs, including first cost, operation cost and maintenance cost.

6.6.10.2 When cost is distributed to all functions, review the total distribution. In the Technical FAST, the ratio of total cost to the cost of critical functions is defined as the value index. In the Task-Oriented FAST, the ratio of the total cost to the Basic and Assure Dependability functions is defined as the value index. The value index varies from 1.5 to 6.0. As this ratio gets higher, the opportunity to reduce cost is higher for the selected component. A value index of 1.5 means a very basic design with minimum cost of supporting functions. If most of the total cost is spent on critical functions, the value index is approximately 1.5. The construction of a fast food restaurant, for example, will have a value index around 1.5, whereas a luxurious restaurant may have a value index much higher than the fast food restaurant.

6.6.10.3 In Task-Oriented FAST, the ratio of basic to supporting functions indicates how basic the project or component is designed. Opportunity to improve value depends upon the understanding and willingness of the stakeholders to accept the findings and change the ratios to fit the intent of the project. Cost distribution for the type of building affects the four supporting functions. Table 1 shows the highest cost function

TABLE 1 Highest Cost Function Group

High Cost %	Type of Building
Assure Dependability	Industrial building
Assure Convenience	Public buildings (for example, train stations, libraries, and schools)
Satisfy Stakeholders	Any building where more decision makers or stakeholders are involved
Attract Stakeholders	Museums, city halls, monuments

for each of the several types of buildings. In an industrial building, major spending occurs in order to make the building dependable. In a public building such as a train station, major spending will occur in order to make the facility convenient to use; that is, elevators, escalators, stairs signage and corridors.

6.6.11 The team should calculate function cost as follows:

6.6.11.1 Review each building component for its functions and allocate cost accordingly,

6.6.11.2 Summarize all costs of each function, and

6.6.11.3 Compute percentage of function cost and list in the FAST diagram.

6.6.11.4 The attached appendixes consist of two case studies. The first is Appendix X1, a Technical FAST diagram case study that shows the method of the function cost distribution in detail. The second is Appendix X2, a Task FAST diagram case study that uses similar function cost distribution of the elements.

6.6.12 *Function Preference:*

6.6.12.1 Designers gather information to understand the needs, desires and constraints of the project. However, the stakeholders may change their opinion after the project is designed and cost is distributed. Utilize questionnaires/surveys, focus groups, public information meetings or public hearings, and measure preferences as they relate to function cost.

6.6.12.2 For each function, measure and tabulate the function preference of the project.

6.6.13 *Analyze the Functions and Identify Mismatches*—Compare function cost and function preference. Table 2 shows four possible combinations of cost/preference. If the cost of a function is high and the stakeholder thinks its importance is low, the result is a mismatch (Type A in Table 2). On the other hand, if the cost of a function is low and the stakeholder rates its importance as high, a high value is achieved and the stakeholder has a match (Type D in Table 2). These are the two extremes of the cost/preference measurement.

TABLE 2 Illustration of Cost/Preference Combinations

Type of Combination	Function Cost	Function Preference	Function Value
A	High	Low	Mismatch (Mandatory Value Analysis) (VA)
B	High	High	Candidate for VA
C	Low	Low	—
D	Low	High	Match

6.6.14 Use value analysis to propose and develop redesigns to reduce or eliminate Type A combinations. Employ value analysis to develop alternatives to reduce the cost of Type B combinations while maintaining high-preference functions. Maintain the Type D combinations since it is a match. Determine if the Type C combination with low cost is worth further analysis.

7. Report

7.1 Function analysis studies reference the source of all the functions; present either one of the FAST diagrams or a series of key functions; detail the method of cost distribution; document a carefully completed survey of stakeholders' preferences; and analyze, identify, and demonstrate value and mismatches. Use the identified value and mismatches as a basis to develop ideas in a value analysis study. This last step is the major difference between a cost reduction method and a value analysis study.

8. Keywords

8.1 building economics; cost efficiency; cost/preference combinations; function analysis; function analysis system technique (FAST); project planning; return on investment; risk analysis; UNIFORMAT II; value engineering

APPENDIXES

(Nonmandatory Information)

X1. TECHNICAL FAST CASE STUDY

FIG. X1.1 Median Slope

X1.1 A divided highway in a national park has a 24.4 m (80 ft) wide median (see Fig. X1.1). The median has a slope of 1:4 to accommodate a 4.57 m (15 ft) difference in roadway elevation. This requires a guardwall on the high road to prevent high-speed vehicles from crossing the median and colliding with traffic on the lower roadway. In addition, there are crash cushions at one end of the guardwall to lessen any head-on impacts.

X1.2 The original design proposed a concrete guardwall faced on both sides and capped with stone masonry (see Fig. X1.2). The core wall was 230 mm (9 in.) thick with a reinforced concrete footing. The higher order function of the guardrail is to assure safety and the causative function is to provide barrier.

X1.3 The cost of the wall was estimated at $520 000; the cost of the crash cushions at $40 000; and the cost of providing a 1:4 slope rather than the standard 1:2 slope at $100 000 for a total of $660 000.

X1.4 The function *Assure Safety* was also fulfilled with an alternative design - a wooden-faced, steel-backed guardrail and a 1:2 slope costing $160 000 (see Fig. X1.3).

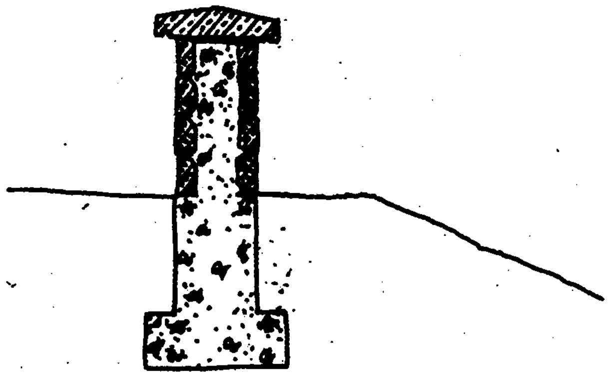


FIG. X1.2 Concrete Guardwall

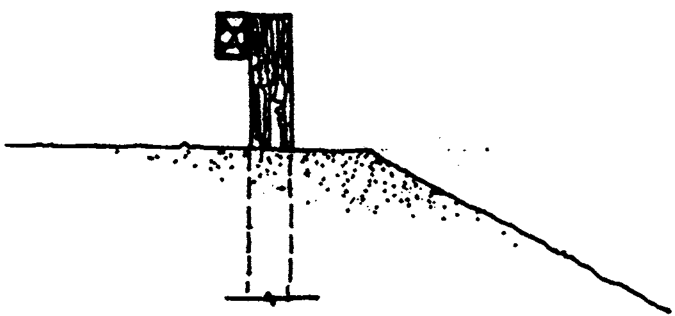


FIG. X1.3 Alternative Guardrail

$$\text{The value index is:} \quad \frac{\text{Total Cost}}{\text{Cost of Critical Functions}} \quad \frac{\$660\,000}{\$160\,000} = 4.13 \tag{X1.1}$$

Since this is a relatively high index, there is opportunity to reduce cost and improve value (see 6.6.10.2).

X1.5 After studying numerous possible functions of the guardrail, it was determined that the guardrail should fulfill the following:

X1.5.1 Protect traffic,

X1.5.2 Prevent crossover,

X1.5.3 Deflect vehicle,

X1.5.4 Protect (errant) driver,

X1.5.5 Minimize (vehicle) damage,

X1.5.6 Protect property,

X1.5.7 Enhance appearance, and

X1.5.8 Reduce maintenance.

X1.6 Fig. X1.4 lists the components and their functions. Fig. X1.5 lists the function cost distribution. The details of the distribution are explained below.

X1.7 The distributions are classified in the Technical FAST diagram (see Fig. X1.6). Allocation of the cost to each function is based on the following logic:

X1.8 The guardwall is composed of two elements: concrete wall and stone facing. Cost of stone facing is estimated at $330 000. Since the roadway face of the guardwall receives the impact of vehicles it is assigned the function *Deflect Vehicle*. This facing should be detailed to be readily replaced after damage. However, the *Deflect Vehicle* function could be accomplished at a lesser cost by a concrete facing at an estimated cost of $40 000. The remainder of the cost of the masonry ($290 000) is allocated to enhance appearance (refer to Fig. X1.2).

X1.9 Cost of the concrete ($190 000) wall is divided into three functions: (*1*) *Protect Traffic*, (*2*) *Prevent Crossover*, and (*3*) *Reduce Maintenance*. A metal plate guardrail for a cost of $40 000 (see Fig. X1.7) can achieve *Protect Traffic* on the lower level roadway. The concrete wall footing was built 900 mm (3 ft) below the grade to eliminate settlement by frost action. The cost of this part of the wall ($60 000) was allocated to the function; *Reduce Maintenance* (see Fig. X1.8). The rest of the wall cost ($90 000) was allocated to the function *Prevent Crossover*.

X1.10 When a single element satisfies multiple functions, function cost allocation can be done in different ways. The value analysis team must agree on logic and should be consistent in their approach to all elements of a project.

X1.10.1 It can be assumed that all functions are equally important and therefore the cost will be equally divided, or

X1.10.2 One function is so important and therefore the total cost of the element is assigned to the critical function and the other functions will be assigned zero, or

X1.10.3 Each function is weighted differently and the cost will be allocated according to their assumed weight of importance.

X1.11 For crash cushions, the team distributed the cost with an assumed weight of importance.

X1.12 Crash cushions ($40 000) are provided to reduce severity of collisions from head-on impacts of roadside obstacles by decelerating the vehicle to a safe stop. This cost was divided into three functions: (*1*) *Minimize Vehicle Damage*, (*2*) *Protect Property*, and (*3*) *Protect (Errant) Driver*.

X1.13 The cost difference between 1:2 slope and 1:4 slope ($100 000) was allocated to the functions *Reduce Maintenance* ($50 000) and *Enhance Appearance* ($50 000).

X1.14 Post function analysis, which is part of value analysis, is presented here to demonstrate the total process.

X1.15 Since the value index of the guardwall as designed $\left(\frac{\$660\,000}{\$170\,000} = 3.88\right)$ is high, consideration was given to alternatives that would reduce the cost of the non-critical functions. Several alternatives were developed and submitted to the owner. Because of the surrounding park it is essential that careful consideration be given to aesthetics. The owner was reluctant to eliminate the stone facing and have an exposed concrete wall. However for the 1:4 slope and the design traffic speed, a barrier is not considered absolutely necessary.

X1.16 It was therefore agreed to eliminate the barrier entirely and revise the median in the following manner (see Fig. X1.9):

Identify Functions		
Component	**Function**	
	Verb	**Noun**
Stone Facing	Enhance	Appearance
	Deflect	Vehicle
Concrete Wall	Reduce	Maintenance
	Protect	Traffic
	Prevent	Crossover
Crash Cushion	Protect	Property
	Minimize	Vehicle Damage
	Protect	(Errant) Driver
Embankment	Enhance	Appearance
	Reduce	Maintenance

FIG. X1.4 Components and Functions

X1.16.1 Flatten the side slope from 1:4 to 1:6. This provides adequate length for the errant cars to recover and stop. This can be done by increasing the median from 24.4 m (80 ft) to 33.5 m (110 ft) at a cost of $200 000.

X1.16.2 Plant low-level bushes that would obstruct the path of an errant vehicle, slowing it down and protecting the driver. Estimated cost of $40 000.

X1.16.3 This alternative performs the higher order function in a different manner and therefore different functions are needed to describe its action. The function *Prevent Crossover* (Fig. X1.6) has been replaced by *Permit Recovery* (Fig. X1.10), the function *Deflect Vehicle* has been replaced by *Obstruct Path* and the function *Protect Property* has been replaced by *Facilitate Movement*. The function *Permit Recovery* describes the action that permits most errant vehicle drivers to gain control and stop their vehicle. The function "Obstruct Path" describes the action of the low-level bushes in slowing down the vehicle. The function *Facilitate Movement* describes the action that permits many of the drivers to recover control and return to the roadway. The logic for allocation of costs is as follows:

X1.16.3.1 The cost of $50 000 to flatten the slope from the standard 1:2 slope to 1:3 (which facilitates mowing) is allocated to reduce maintenance.

X1.16.3.2 The cost of $50 000 to flatten the slope from 1:3 to 1:4 (which permits a minimum opportunity of an errant driver to recover control) is allocated to permit recovery.

X1.16.3.3 The cost of $100 000 to widen the median and flatten the slope to 1:6 is allocated to protect traffic ($40 000), enhance appearance ($40 000), facilitate movement ($10 000) and Minimize Vehicle Damage ($10 000) (refer to Fig. X1.10). The cost of the low-level bushes is allocated to obstruct path ($20 000) and protect errant driver ($20 000).

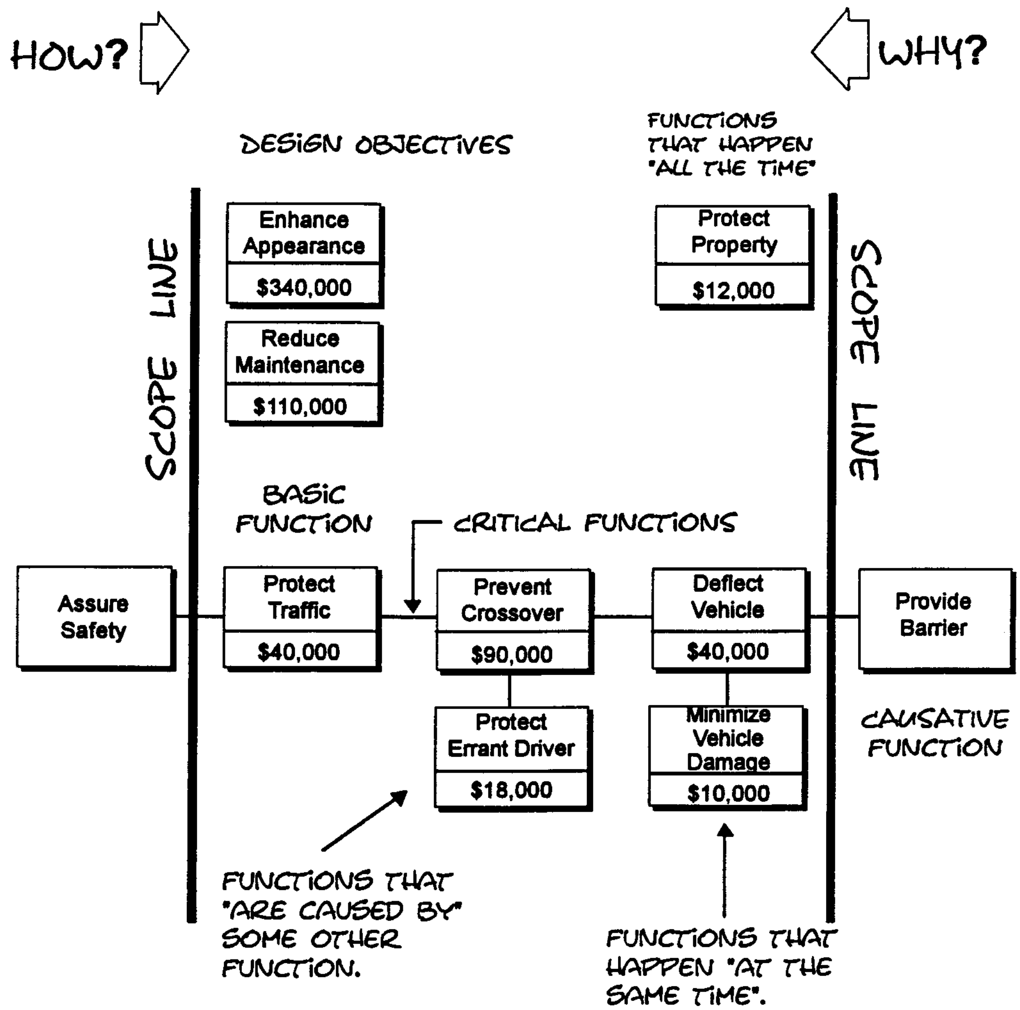
X1.16.3.4 The value index of this alternative is: $\left(\frac{\$240\,000}{\$110\,000} = 2.18\right)$

Function Cost Distribution Work Sheet

Ref.	Component	Incremental Cost	Functions (verb-noun)							
			Enhance Apperance	Reduce Maintenance	Deflect Vehicle	Protect Traffic	Prevent Crossover	Minimize Vehicle Damage	Protect Property	Protect (Errant) Driver
	Stone Facing	$330,000	$290,000		$40,000					
	Concrete Wall	$190,000		$60,000		$40,000	$90,000			
	Crash Cusion	$40,000						$10,000	$12,000	$18,000
	Embankment	$100,000	$50,000	$50,000						
	TOTALS	$660,000	$340,000	$110,000	$40,000	$40,000	$90,000	$10,000	$12,000	$18,000

Total Element Cost $660,000
Critical Functions $170,000

FIG. X1.5 Function Cost Distribution



$$\text{Value Index} = \frac{\text{Total Cost}}{\text{Cost of Critical Functions}} = \frac{\$660{,}000}{(\$40{,}000 + \$90{,}000 + \$40{,}000)} = 3.88$$

FIG. X1.6 Function Analysis Systems Technique
(Technical FAST)
Guardwall as Designed

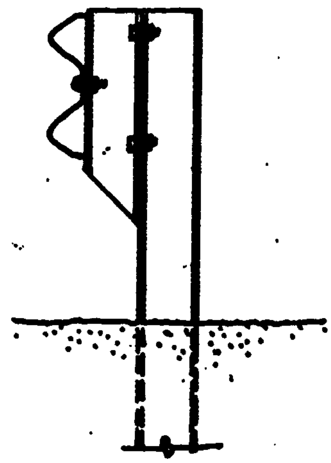


FIG. X1.7 Metal Plate Guardrail ($40 000)

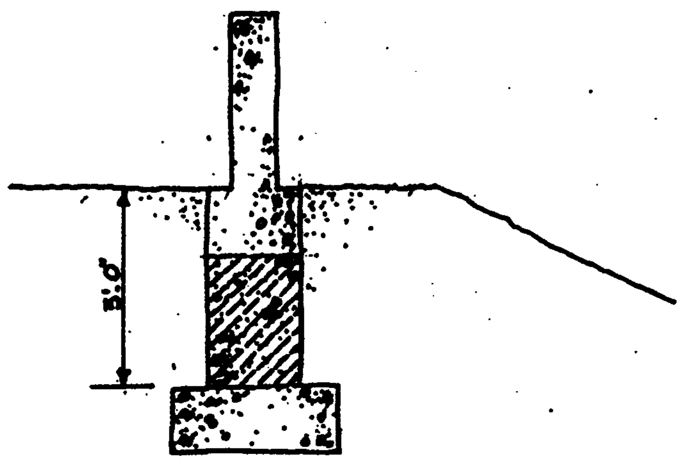


FIG. X1.8 Concrete Wall Footing ($60 000)

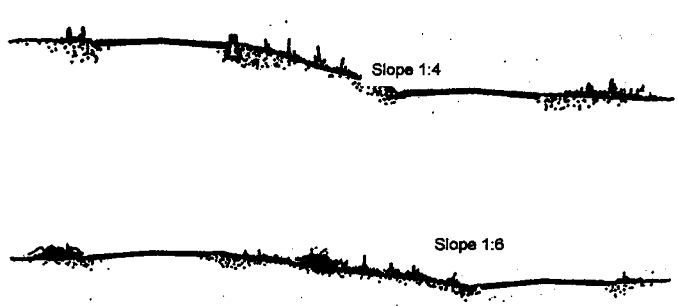
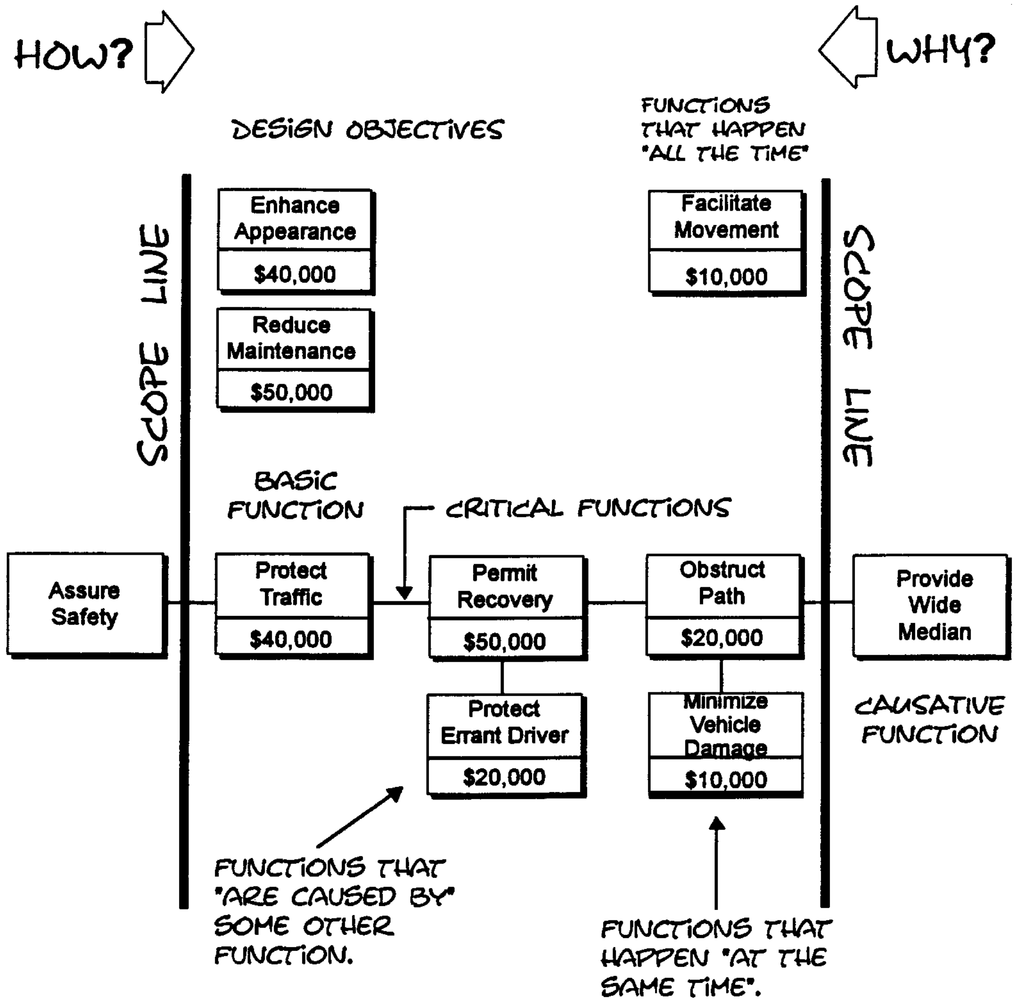


FIG. X1.9 Revision of the Median



$$\text{Value Index} = \frac{\text{Total Cost}}{\text{Cost of Critical Functions}} = \frac{\$240{,}000}{(\$40{,}000 + \$50{,}000 + \$20{,}000)} = 2.18$$

FIG. X1.10 Alternative Barrier Functions

X2. TASK-ORIENTED FAST CASE STUDY

X2.1 An existing treatment plant contains water storage tanks and treatment tanks that are exposed to weather and are therefore difficult to maintain and inspect during extreme cold or snow seasons. These tanks are subjected to extreme winter conditions. In addition, they are expensive to maintain.

X2.2 A proposal was made to enclose and heat the space to reduce the maintenance cost and difficulty (see Fig. X2.1). In the past few years, homes were built surrounding this plant. The residents were not comfortable having an industrial plant in their neighborhood. Since the plant was in existence for some time, they accepted its presence. However, they demanded that the proposed building design decrease the impact of the industrial appearance, and that the rooftop units and other equipment be concealed. The architect proposed the following:

X2.2.1 Earth mound that would conceal the structure;

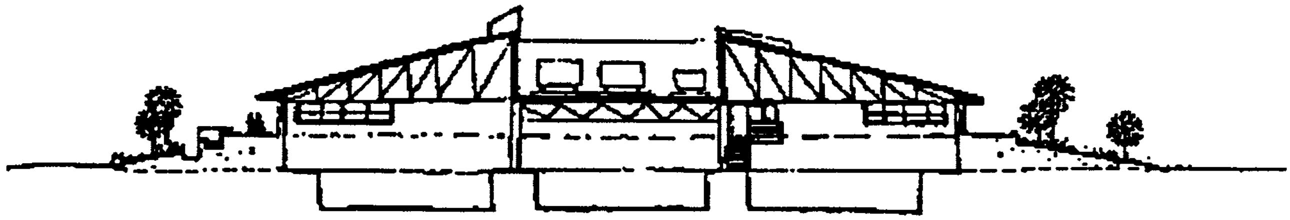
X2.2.2 A series of ramps to satisfy the handicap requirement;

X2.2.3 A series of folded plates for the roof, with special skylights to let in natural light; and

X2.2.4 A visitor's gallery with exhibits for the public to observe the treatment process.

X2.3 All structural members were required to have additional special paint to protect the members. In addition, special insulation and wall designs were proposed to control the relative temperature.

X2.4 Construction was proposed in stages. This assured uninterrupted plant operation and minimum disturbance to adjacent property. The design and location of columns were based on the existing location of water tanks and the capacity of the foundation walls and piles.



Cross Section

Elevation

FIG. X2.1 Enclosed Space

X2.5 The cost of the project improvement was allocated to functions. Cost allocation is similar to the procedure described in Appendix X1. Fig. X2.2 shows the function cost percentage distribution. Table X2.1 summarizes the distribution of function cost.

X2.6 There was some concern about condensation. The specialists from the design group and Value Analysis Team did not agree on the role of this function. The question that arose: "Is it really a condensation problem or perceived condensation problem?" In the FAST diagram, does it belong under *Assure Dependability* or under *Safety Stakeholders* ? After extensive research, it was found to be a perceived condensation problem.

X2.6.1 The VA team identified the following functions as mismatches or candidates for VA:

Function	Function Cost	Function Preference	Function Value
Minimize Condensation	High	Low	Mismatch
Enhance Appearance	High	High	Candidate for VA
Deinstitutionalize Building	High	High	Candidate for VA

The function *Minimize Condensation* (15.2 %) was moved from *Assure Dependability* to *Satisfy Stakeholders* (Fig. X2.3). This resulted in redistribution (see Table X2.2).

X2.7 Post function analysis, which is part of value analysis, is presented here to demonstrate the total process.

X2.8 For an industrial building, it is desirable to minimize cost of the categories, *Satisfy Stakeholders* and *Attract Stakeholders*. A survey of function preference reveals that the owner is willing to eliminate the cost of the function, "Minimize Condensation" if it can be proved that it has no effect on the maintenance of the building. The technical team concluded that some minor design features should be added to maintain proper humidity. Cost of this improvement, *Minimize Condensation*, is 4.2 % and is added to the *Assure Dependability* group.

X2.9 It is also recognized in the survey that cost of the architectural features is excessive. The roof skyline features were eliminated and the entrance mound and landscape designs were simplified. The FAST diagram with function cost percentage distribution was revised to reflect the changes. This is shown in Fig. X2.4.

X2.10 The distribution after value engineering is as follows:

Basic Functions	31.3 %
Assure Dependability	29.6 %
Assure Convenience	18.0 %
Satisfy Stakeholders	9.5 %
Attract Stakeholders	11.6 %

X2.11 For an industrial building, basic functions and functions that make it dependable should cost the most (31.3 + 29.6 = 60.9 %). The *Attract Stakeholders* group should cost the least. Due to the concern of the neighborhood, 11.6 % can be accepted as a reasonable percentage.

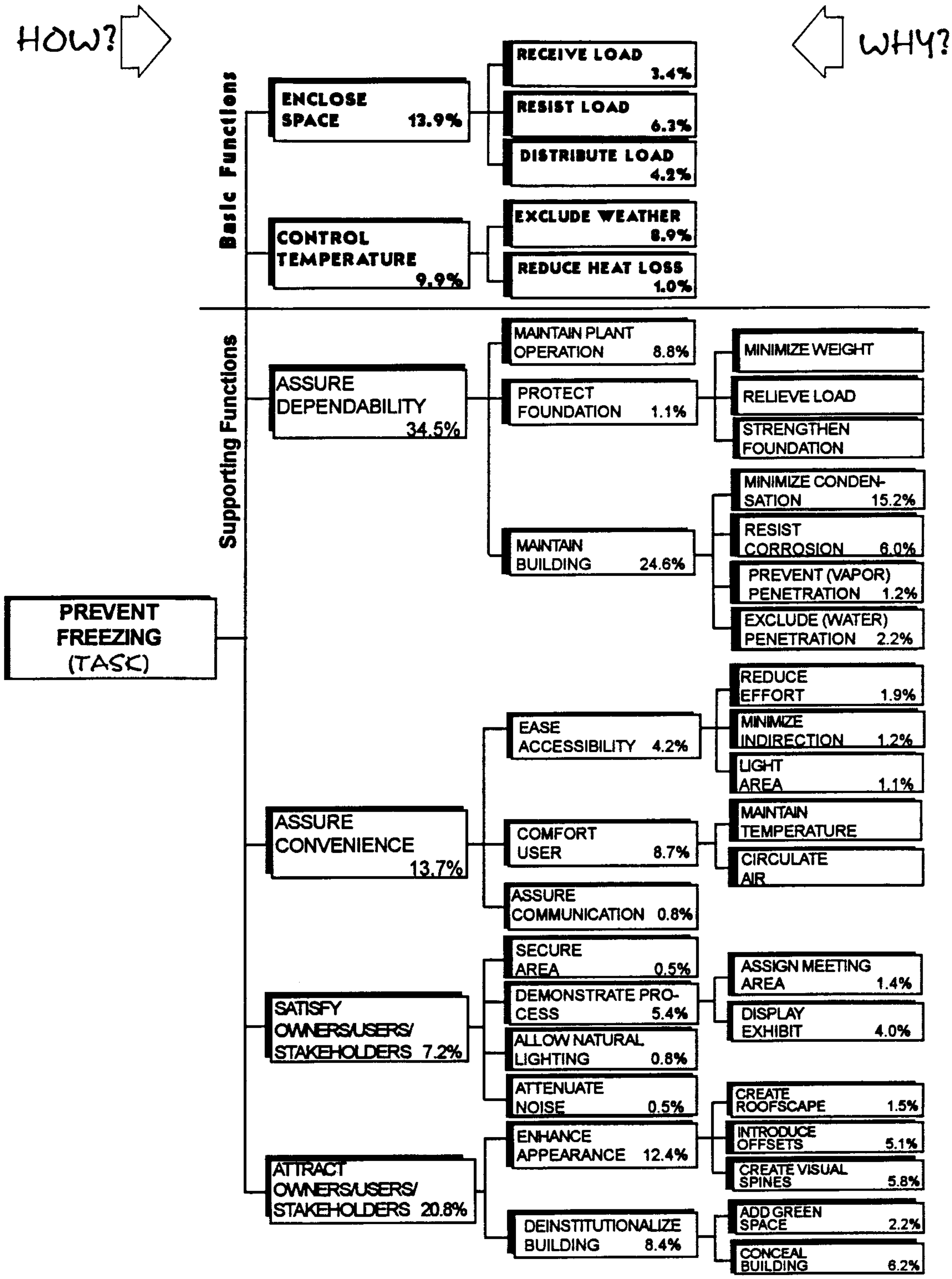


FIG. X2.2 Cost Percentage Distribution

TABLE X2.1 Function Cost Percentage Distribution

Basic Functions	23.8 %
Assure Dependability	34.5 %
Assure Convenience	13.7 %
Satisfy Stakeholders	7.2 %
Attract Stakeholders	20.8 %

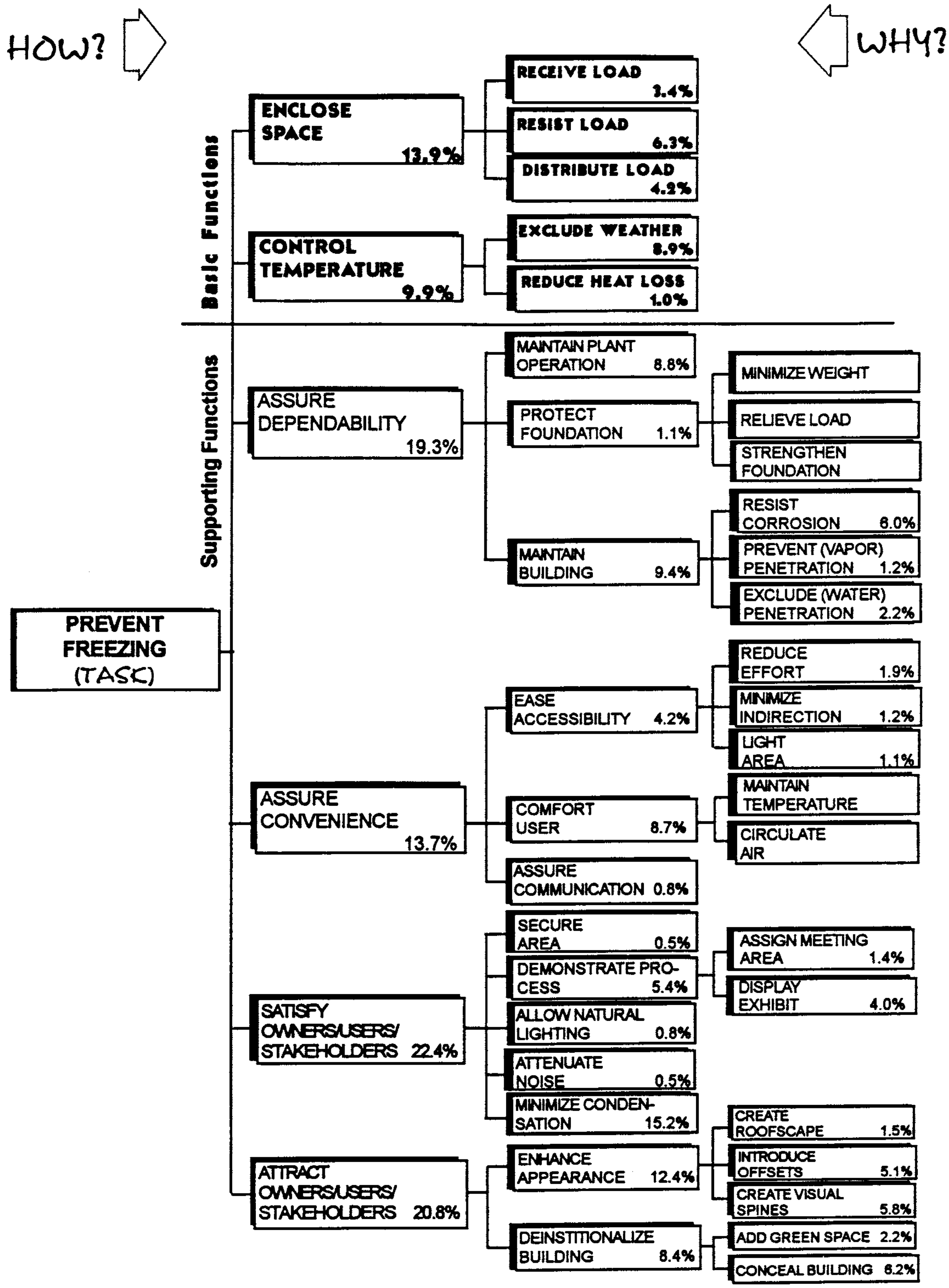


FIG. X2.3 Function Redistributions

TABLE X2.2 Function Cost Percentage Distribution After Research

Basic Function	23.8 %
Assure Dependability	34.5 – 15.2 % = 19.3 %
Assure Convenience	13.7 %
Satisfy Stakeholders	7.2 + 15.2 % = 22.4 %
Attract Stakeholders	20.8 %

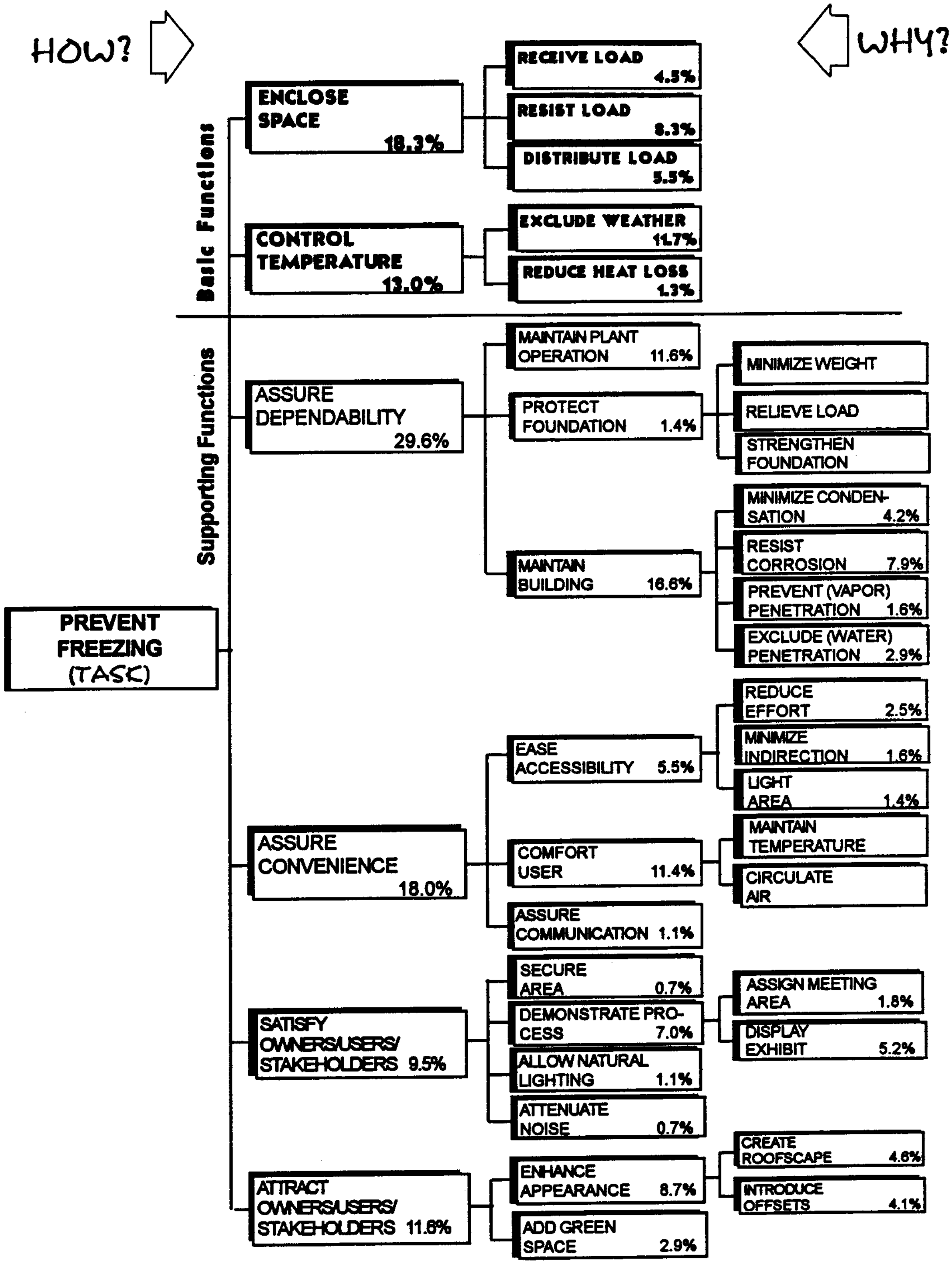


FIG. X2.4 Function Cost Percentage Distribution